

Carnegie Mellon

Materials Science and Engineering Seminar Series

Materials Research at Carnegie Mellon

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“Experimental Observations and Theoretical Simulations of Resistance Switching Behavior”

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11:30 A.M. Seminar in Baker Hall A51

Refreshments precede seminar at 10:30 A.M. in 2325 Wean Hall

Many oxides are known to show resistance switching behavior when they are made in metal-insulator-metal heterostructures. They have gained much attention as candidates for data storage. However, the physical theory that explains this behavior is still unclear. A common feature of many models is oxygen vacancy migration, although no quantitative description has been presented. In this work, we have developed a quantitative model that includes mobile oxygen vacancies.

First, experiments were done with metal/Cr-doped SrZrO₃/SrRuO₃ structures. The effects of the Cr-content and the thickness of the SrZrO₃ film were examined by their current-voltage characteristics (IVCs). The results provided guidance to develop a switching model. From the IVCs, space-charge-limited current (SCLC) was identified as the dominating electrical transport mechanism for both resistance states. The two coefficients in the SCLC equation transitioned between two values upon the switching event. Also, a steep increase of resistance with respect of thickness was observed. For high Cr-doping levels, $R \propto t^3$ was observed, while for low Cr-doping levels an even stronger relationship was observed.

Next, IVCs of SCLC were simulated using the commercial TCAD software. A one-dimensional model was developed with the two contacts designed to behave as carrier-injecting electrodes, providing free electrons (or holes) into the insulator. Simulated IVCs showed good agreement with SCLC. Simulations made with a series of doping levels and thicknesses provided a plausible explanation for experimental observations made earlier.

Finally, mobile donors (oxygen vacancies) were introduced into the switching model and simulations were performed. Donor motion was allowed only when the electric field inside the functional layer reached a threshold value. The two electrodes were modeled as blocking interfaces for donors, such that the total donor concentration was conserved in the functional layer. In the model, donor motion was driven by electrical and chemical field imposed by two blocking electrodes. Numerical calculations of donor motion were made by iterating between matlab, to calculate new donor profiles,

and TCAD, to calculate electrical potentials. Iterations were performed until a converged distribution was obtained at each applied voltage. When donor motion was driven by the combined fields, switching in the IVC was observed, as will be discussed. The simulation results suggest that a model combining chemical and electric fields may ultimately yield a quantitative description of the resistance switching phenomenon.

Sukwon received his Bachelor degree in Materials Science and Engineering from Yonsei University in 2003 and his Master degree from Carnegie Mellon University in 2004. He is currently a Ph.D. candidate under the guidance of Prof. Salvador, Prof. Bain and Prof. Skowronski.